DEVELOPMENT OF WIRELESS COMMUNICATION

GRADUAL INCREASE OF RANGE

RAPID GROWTH OF BROADCASTING

By the Marchese Marconi

Wireless telegraphy may quite rightly trace its development back to the days of Michael Faraday, for it was through his discovery in 1830 that it was not necessary for two electric circuits to be in actual physical contact for electric energy to pass between them that he directed attention to the medium separating the two electric circuits which plays such a great part in wireless communication.

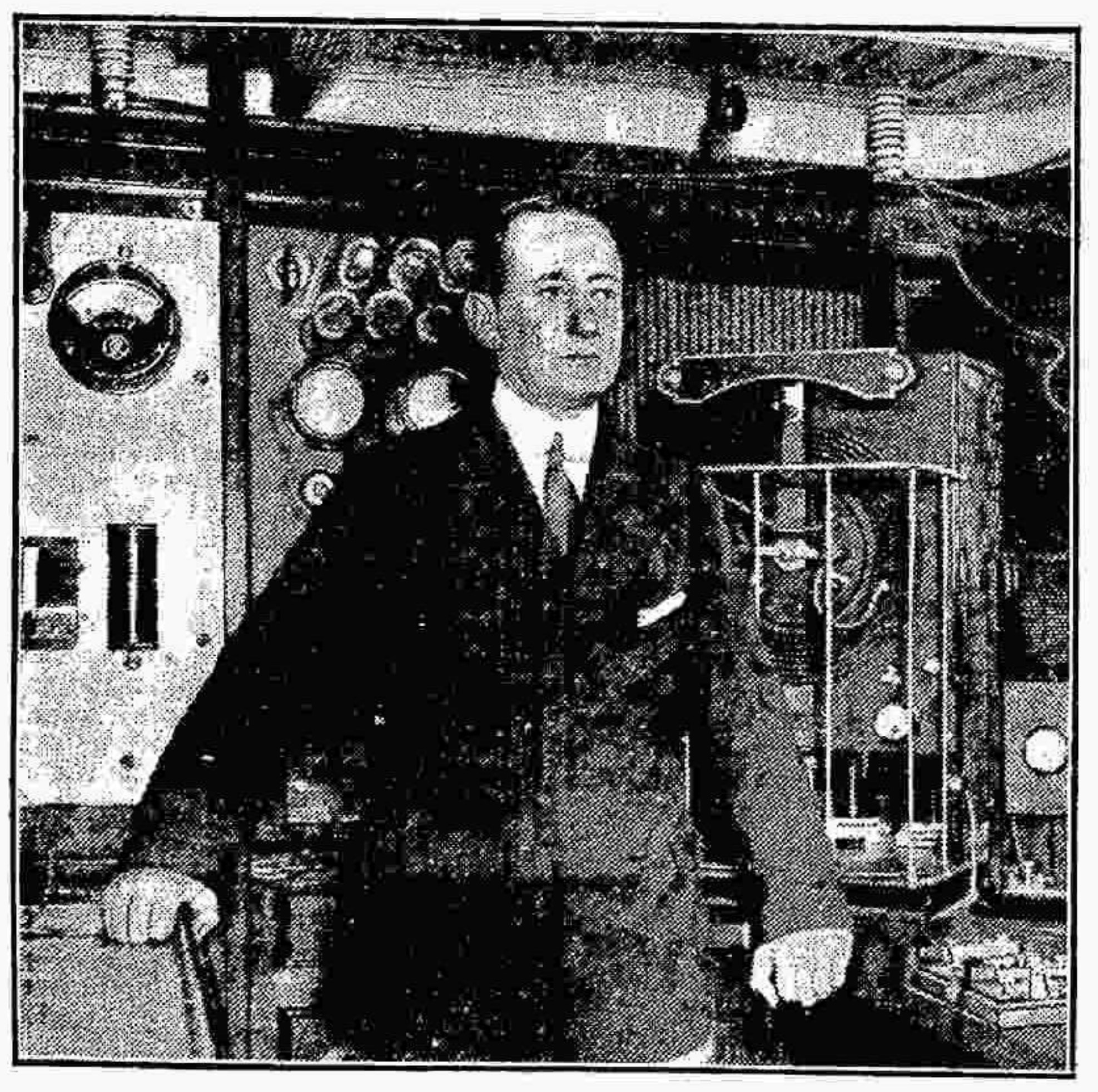
Its importance was again emphasized when in 1837 he showed for the first time that the charge given to a condenser does not reside in the conducting plates but in the insulating medium between them: and then he proceeded to explain this effect—which might take place in a solid material such as glass, or a gaseous material such as air—by introducing the conception of an electrostatic field composed of "tubes of force." The theoretical study of Clerk Maxwell of the movement of these tubes of force in the ether, the hypothetical medium of extremely fine texture which fills all space and the interstices between the air molecules, resulted in the publication in 1865 of his masterly Electromagnetic Theory, wherein he visualized the independent existence in space of closed loops or tubes of force as constituting the elementary components or wireless waves.

Heinrich Hertz demonstrated in 1888 the existence of such free waves, using the spark discharge of an electric condenser to start them; a method which has persisted—though with great improvements in both electric circuits and operation—right up to the present day, as one of those principally employed for ship service. Hertz used parabolic metal reflectors to confine the waves to a given path between the transmitter and the receiver, the wavelengths employed being from about 70cm. to 6 metres.

When I began my researches at Bologna, with the express intention of utilizing electromagnetic waves for telegraphing across space, and again in 1895, when I gave demonstrations of the first practical working apparatus, I used similar reflectors in combination with a form of spark oscillator designed by Professor Righi which enabled me to employ a still shorter wavelength, about 10cm., in conjunction with a coherer-receiver and Morse inker which produced a record of the Morse signals transmitted. It was with these very short wavelengths that I gave my first demonstration to the British Post Office in 1896.

CONQUEST OF SPACE

During my early experiments I was able greatly to increase the transmitting range, or, in other words, to telegraph over what were then considered long distances, by an important departure from the methods used by Hertz and his successors up to that time, which consisted in connecting the transmitting and receiving instruments each to an elevated conductor and to earth. I was thereby enabled to discover that the possible range of communication increased very rapidly if the height above ground of the elevated conductors or aerials was increased; so that in a comparatively short time it became possible to telegraph over distances of 30 miles. The reflector tests thereupon gave way to research and development work employing aerials, as this method offered promise of more immediate results, and the working wavelengths in consequence were increased to about 150 metres and more.



THE MARCHESE MARCONI, who was the first to devise a practical means by which electromagnetic waves could be made to provide a method of telegraphic communication.

The work of Sir Oliver Lodge and my tuning patent of 1900, applying the important principle of resonance to the oscillatory circuits, mark the next stage in the progress of wireless; and then, with the progressive increase in power of the apparatus, the height of the aerials, and the increase in the wavelengths employed, began the conquest of space which has culminated in the world-wide communication networks of the present day. In this article I can refer only to a few of the more notable events and developments that have since taken place.

In December, 1901, by means of specially constructed stations, I was able for the first time to transmit and receive telegraphic signals right across the Atlantic Ocean from Poldhu in Cornwall to St. John's, Newfoundland, over a distance of 1,800 miles. This achievement, which in itself constituted a discovery, confirmed my opinion that electric waves would not be stopped by the curvature of the earth and could therefore be made to travel any distance on our planet, a view I had held for some years and in the face of a considerable body of opposition. In this connexion, however, it is a pleasure to recall the assistance I derived from *The Times*, which maintained, throughout the long period of discussion that followed upon my early Transatlantic tests, an attitude of unfailing encouragement and support.

This discovery gave such an impetus to the development of communication by wireless telegraphy that, within a comparatively few years after the single letter "S" had been heard by wireless across the Atlantic, every important country of the world possessed a wireless telegraphy organization. Communication with Australia was accomplished in 1918 when the first messages were transmitted through my Carnarvon station to Sydney, New South Wales, from Mr. W. M. Hughes and Sir Joseph Cook. Early in 1902, during a voyage in the American liner Philadelphia, I noticed that I could receive messages up to a distance of 700 miles by day and 2,000 miles by night, thus discovering the now well-known fact that wireless signals transmitted by wavelengths of a few hundred metres can usually be received over much greater distances by night than during the hours of daylight. For these tests the total transmitting power employed was 12kw., the wavelength 400 metres, and the height of the aerial 200ft.

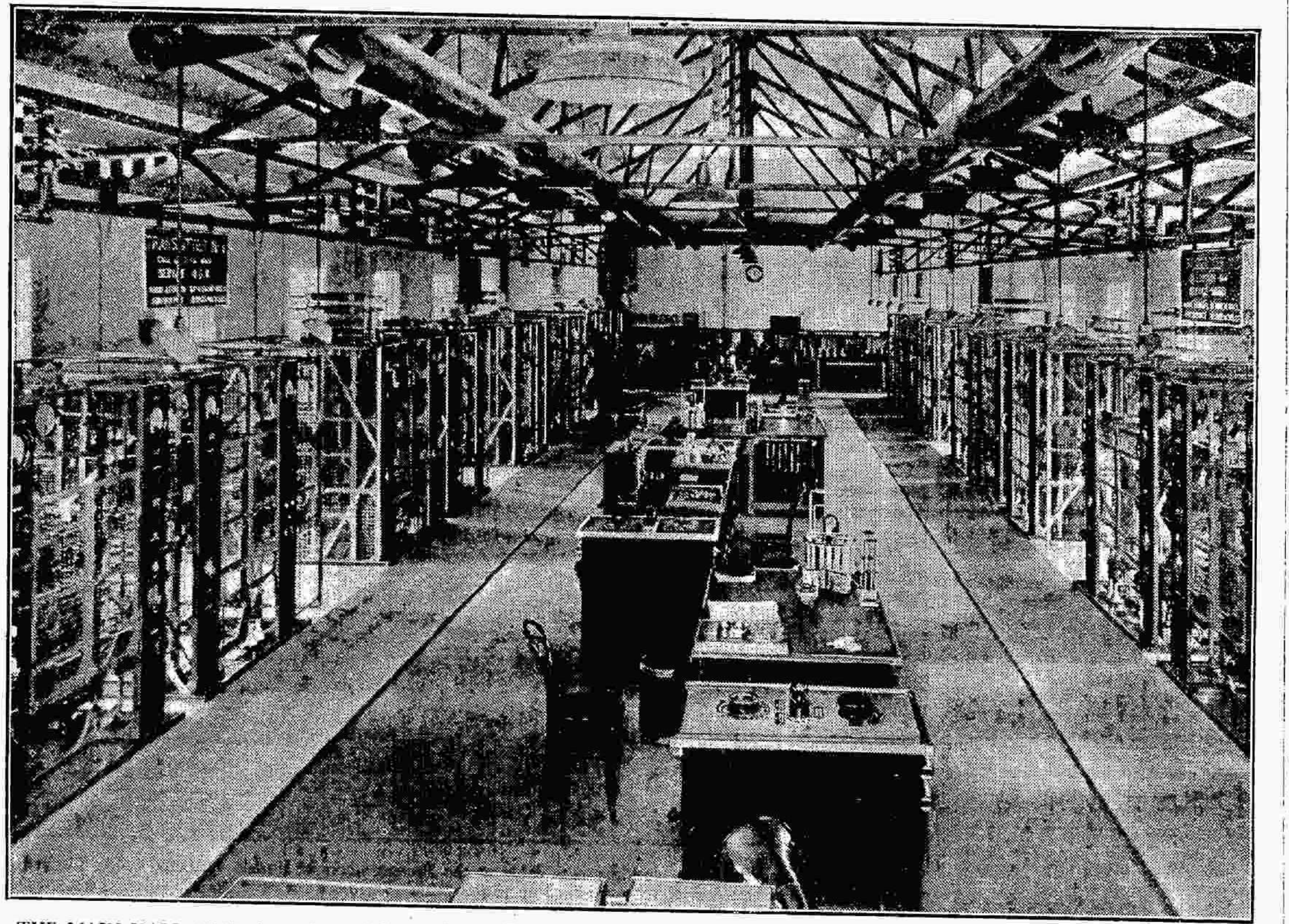
In the years that followed, progress in long-distance transmission provided a record of steady increase in power and wavelength until, in 1923, the peak of the long-wave era was reached when the British Post Office began the erection of the Rugby high-power long-wave station, and the Marconi Company, in agreement with the Dominion Governments, put in hand stations of similar size in Australia, South Africa and India to communicate with Rugby, each station employing 800ft. steel towers to carry the aerial, with about 1,000kw. transmitters designed to work on wavelengths of 20,000 to 30,000 metres.

The progress made with the long-wave antenna system had been so rapid, so comparatively easy, and I might say so spectacular, that for many years it had distracted all attention and research from short waves, and this I think is to be regretted. Nevertheless, the art of wireless telegraphy and its technique had been making very rapid progress.

The systematic investigation of the possibility of using short waves for radio telegraphy and telephony was again taken up by me in Italy early in 1916, and, with the assistance of Mr. C. S. Franklin, tests were carried out with a directive system which was subsequently named the Beam System. During the first tests, utilizing two-metre waves, a range of six miles was obtained; subsequently this distance was increased to 20 miles. In the course of some wireless telephone tests in 1919 a range of 80 miles was obtained by Mr. Franklin across the Irish Sea utilizing a wavelength of 15 metres; and in 1921 two-way telephonic communication was obtained between Hendon and Birmingham, a distance of 97 miles, utilizing reflectors.

The two-electrode thermionic valve invented by Sir Ambrose Fleming in 1904, and the three-electrode valve invented by Dr. Lee de Forest in 1907, had undergone intensive development during the Great War, and by 1923 the valve transmitter had completely ousted the spark transmitter for practically all communication purposes except for a few of those connected with shipping. The introduction of the continuous wave method of transmission by means of the valve also removed the restriction of power limitation imposed by the spark method on the use of short waves; and in 1923-24, by means of elaborate transmission tests between Poldhu and my yacht Elettra in various parts of the Atlantic and the Mediterranean, and by tests between Poldhu, North and South America, and Australia, I was able thoroughly to investigate the possibility of employing short waves from 90 metres downwards for long-distance communications, particularly when directed by reflectors. During 1924 I was able to discover that by employing wavelengths of the order of 32 metres transmission over the greatest distances was possible during the hours of daylight.

These researches proved so satisfactory that early in 1924 the Marconi Company, acting on my advice, decided not to complete the long-wave stations in course of erection in the Dominions, and put forward the proposal of carrying out all Imperial wireless telegraphic and telephonic communications by means of my short-wave directive system. As a result of these developments, the British Government, in July, 1924, concluded an agreement with the Marconi Company for the erection of short-wave stations on the beam principle and having 20kw. transmitters to communicate with similar stations in Canada, South Africa, India, and Australia. Acceptance was to be conditional on a continuous seven days' test working duplex, at not less than 100 words a minute simultaneously both ways, and exclusive of any repetitions necessary to service accuracy, for 18 hours a day on the Canadian circuit, 11 hours on the South African, 12 hours on the Indian, and seven hours on the Australian. These conditions were complied with, and the British stations were handed over to the British Post Office at intervals from October, 1926, to July, 1927—the last Imperial stations to be completed being Ballan, Australia, and Drummondville, Canada, in June, 1928. Twenty-four hour services soon came into operation, the wavelengths all being within the band of 15 metres to 40 metres.



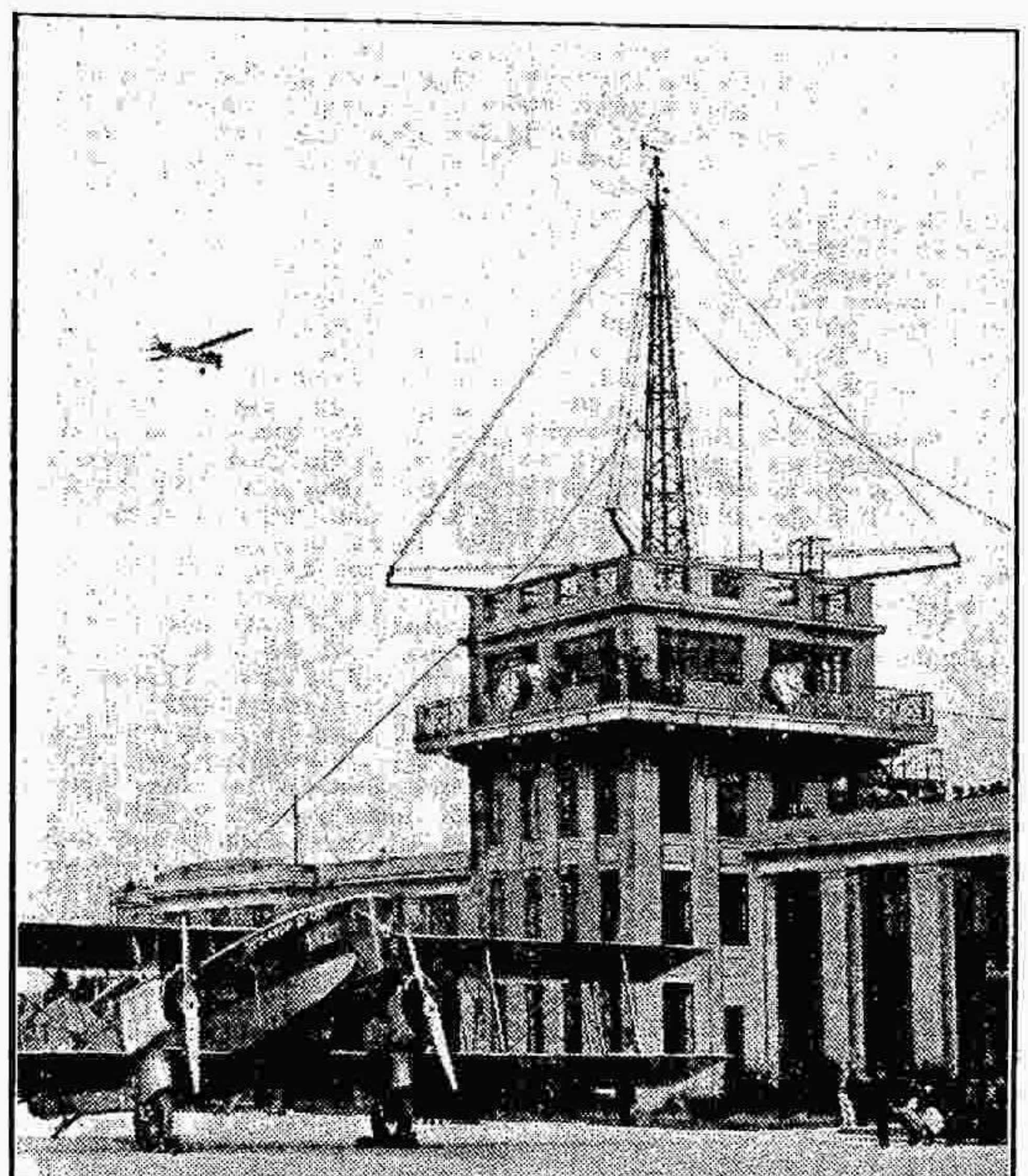
THE MAIN HALL of the beam-transmitting station at Dorchester. It contains seven beam transmitters, used for sending high-speed telegraph traffic to the United States, Argentina, Brazil, Egypt, Syria, and the Far East. In the middle, between the transmitters, are the control tables, from which the machines supplying current for the valves are started up and the current supply is regulated.

The Imperial Beam Station organization, under the name of Empiradio, rapidly built up a strong traffic service which made serious inroads into the cable traffic. This led to the formation, in September, 1929, of Imperial and International Communications, Limited, which took over the control of the Empiradio, Imperial and Pacific Cables, the Marconi Wireless and the Eastern Telegraph Cable systems, and is now the centralized authority for all the most important commercial wireless telegraph services conducted from this country. As Mr. Ramsay MacDonald stated in the House of Commons: "The cable companies fell upon evil days when the beam wireless was made a businesslike proposition." The wireless network over the whole world, which is shared between the British organization, the Radio Corporation of America, Transradio representing the German interests, the Société Radio France, and several other important groups, is to-day both effective and competitive. All the systems intercommunicate, and a high standard of technical efficiency and service is maintained. Every year the number of wireless communications increases, and the difficulty of arranging wavelengths on which the new services may send their traffic without interference with existing services becomes greater.

Because their propagation is not assisted by the upper atmosphere, and their application is therefore more restricted, electromagnetic waves of 10 metres in length and less are still available for a very considerable number of channels, and the Italian Government has recently opened a service between Rome and Sardinia employing apparatus developed by my assistants which operates on 9 metres. Where the earth's curvature or other obstacles do not interfere, communication channels on still shorter wavelengths are likely to be opened up, and to me it is a matter of great personal interest to realize that in my present researches on the use of extremely short wavelengths of one metre and less for commercial purposes I have now resumed the study of those wavelengths which I employed when I made my first successful demonstrations of telegraphy without wires 36 years ago. In this brief review, however, the importance of the point-to-point fixed services must not be allowed to overshadow the very valuable work being carried out by wireless in other fields. Its systematic use in the Mercantile Marine, which dates back to the year 1900, when the first permanent wireless telegraph installation was fitted by my company in a German ship, the Kaiser Wilhelm der Grosse, now embraces some 15,000 vessels of the world's shipping, which intercommunicate and exchange navigational and commercial traffic with a network of Government coast stations in every maritime country: and the valuable aid which wireless offers to the safety of life at sea is further recognized in the provision of numerous wireless beacon stations, which send out distinctive signals to enable ships within range to take their own bearings.

Of more recent growth is the application of wireless to the navigation of aircraft. Eleven years ago every British machine regularly flying on the London-Paris air route was equipped with the wireless telephone, and the aerodromes at Croydon, Lympne and Pulham with transmitters and direction-finder sets which enabled them to give the planes their bearings and take messages from them at any time *en route*. The value of such a service when the visibility is poor cannot be over-estimated. To-day every commercial passenger-carrying plane in the world is required to carry wireless; and on the most important air routes wireless beacon transmitters are being established to enable the pilot to make the air port without having to ask for his bearings to be given him by the ground stations.

There is little I need say about the phenomenal growth of Broadcasting, since it is known to every one. The first concert from Chelmsford in 1920—when Dame Nellie Melba sang into a telephone service microphone, the 2,000-metre transmission being picked up by listeners within a range of 800 miles—started a movement which spread rapidly to all countries. A new art and a new industry have been created, and a new factor has taken a permanent place in national and international life. The conquest of space by electricity, which was initiated by electromagnetic induction discovered by Faraday and by the electric waves foretold by Maxwell, has given mankind not only a new and powerful means of scientific research, but also a new force of civilization and progress which knows no frontiers and can even push out into infinite space where never before, perhaps, has any manifestation of the activity and thought of man been able to penetrate. The extension of what is called Broadcasting—which constitutes the most powerful and rapid method of disseminating information, entertainment, and education that the world has ever known—cannot but bring about a more solid understanding between peoples. It enormously increases what man can do with his own voice or with his own mind. It enables him instantaneously to multiply himself a hundred, a thousand, or a million fold in the expression of his power, his influence, or his genius. Transatlantic and Imperial wireless telephony and the transmission of pictures by wireless are among the latest contributions by research engineers to the facilities for communication which the business world now possesses; and should the intensive work on television now in progress in our laboratories give us, as we hope it will at no distant date, the results for which we are striving, the public will again be afforded an opportunity of assisting in the creation of a new art and industry, that of visual broadcasting.



WIRELESS AND AIRCRAFT.—The Wireless Control Tower at Croydon Aerodrome. The duty-officer can communicate with aeroplanes in flight and advise pilots of their position.

INDUSTRY BUILT ON SCIENCE

INVESTIGATOR AND CONSTRUCTOR

PROFIT FROM RESEARCH

By Sir Richard Gregory, D.Sc.

The amount of capital invested in electrical lighting and power supply in the world exceeds £5,000,000,000, and in Great Britain alone more than £500,000,000. All the ramifications of the great electrical industry in which this capital is used have been developed from the discovery of magneto-electricity made by Faraday a century ago as the culminating point of purely scientific researches which no one then regarded as of any practical value. A new era, that of electricity, may be said to have opened with this discovery. The inventions of the eighteenth and early nineteenth centuries came from the workshop rather than from the scientific laboratory. Machines were devised and operations developed largely by trial and error methods, and academic research had few points of contact with industrial practice. The characteristic of the new age is the utilization in industry of principles, properties, and products revealed by scientific research, whether carried on solely in the pursuit of knowledge or with a practical purpose in mind.

It is usual to make a distinction between scientific and industrial research, but really they are complementary to one another. Most of the investigations carried on in academic laboratories, and recorded in the *Proceedings* of scientific societies, are inspired by the desire to explore the realm of Nature and enlarge the boundaries of knowledge. In the world of science research is judged by its fundamental significance and not by its money-making capacity. Applications of the results may afterwards be found, but they are only incidental to the inquiry and are rarely the main object of the work. Industrial and technical research, however, is primarily concerned with the production of something of direct service or with problems of manufacture and construction, the solution of which will suggest new lines of industrial progress.

To the inventor or industrialist discoveries are things to be used and not ends in themselves, as they are to the man of science. He seeks not so much to know Nature as to circumvent her; and the research which he undertakes has for its object the artificial preparation of substances which are naturally rare or have peculiar properties, the production of a new process or the improvement of an old, the design of machines which will increase his power over Nature and of instruments which will enable him to laugh at limitations of time and space.

Faraday carried on his researches with the single aim of acquiring new knowledge, yet his work laid the foundation of the whole industry of electrical engineering. In the growth and development of the industry, however, technical research undertaken with definite practical purpose has played a most important part. In the evolution of electrical machinery and plant, and in all other branches of applied electricity, progress has been achieved by cultivating close relationship between creative science and inventive genius, and by men able to interpret scientific theory in terms of industrial practice. Of the importance of research to the electrical industry, or of the notable improvements in machines, appliances, and processes brought about in the industry by special investigation, there can be no question. The greatest research laboratories in the world are connected with electrical corporations, such as those of the Western Electric, General Electric, and Bell Telephone companies in the United States and the General Electric Company at Wembley in England. With no other industry is science allied so closely as with the electrical industry, and no other industry has derived greater profit from this cooperation of practice with theory. To the recognition of the value of research by the leading firms engaged in the industry, and of the capacity of technologists to direct and manage the business itself, is largely due the flourishing condition which the industry has reached.

The first dynamos were constructed on rule-of-thumb methods and were, in consequence, inefficient. Knowledge acquired by many investigators established the scientific principles which enabled dynamo machines to be designed according to precise specifications. In every stage of the evolution of the modern transformer and dynamo, problems have been solved by persistent research, and in many cases the developments have been due to the use of new materials or properties discovered in scientific laboratories. A striking example of this is afforded by electric lighting, which was the first use made of electric supply. The original carbon filament incandescent lamp of Swan and Edison has been superseded by lamps in which a tungsten filament is used. The element tungsten was obtained in the metallic form towards the end of the eighteenth century, yet it was not until nearly a century later that the metal began to assume industrial importance in the production of high-speed tool steels, for which purpose large quantities are used. Attempts had been made to construct filaments of tungsten for incandescent lamps, but the results were unsatisfactory until 1906, when Dr. Coolidge, in the United States of America, devised a means of producing the metal in a ductile form, so that it could be drawn out into very fine wires. A curiosity of the laboratory has thus become a valuable product of industry. Because of its high melting point and resistance to volatilization at a high temperature, tungsten has proved to be the most suitable filament material for incandescent electric lamps; and the world consumption of such lamps, which give a great increase of candle power hours for the same expenditure of current, is now about 1,000,000,000 a year. It was estimated several years ago that the annual saving brought about by the use of tungsten filament lamps in the place of the old carbon filament was nearly £50,000,000.

A further development in which advantage is taken of scientific discovery is the gas-filled lamp. The chief gas used for this purpose is argon, which was first isolated from atmospheric air by Lord Rayleigh and Sir William Ramsay in 1895. Another gas discovered in the air shortly afterwards as the result of scientific research is neon, which is used in electric discharge tubes familiar in the pink glow of advertisement displays and for the lighting of aerodromes and air routes. On account of its penetrating quality the neon light from the Croydon beacon can be seen by airmen when flying over France. Research is now being carried on to produce a white glow light by the mixture of different gases and special glass for the bulbs or tubes. It seems highly probable, therefore, that before long electric lighting will be done by glowing gases enclosed in tubes instead of incandescent metallic filaments.

Röntgen's discovery of X-rays was an incidental result of an investigation into the nature of the electric discharge in glass tubes or bulbs containing extremely rarefied gas. Similar scientific researches into the nature of electricity led to the invention of the thermionic valve used in wireless communication, and also to the discovery of the nature and properties of the electron, upon which the powers of such valves are based. When Röntgen observed in 1895 that the rays from a vacuum-tube were not only able to excite fluorescence but also capable of passing through various substances and recording their existence upon a photographic plate neither he nor anyone else at the time anticipated that a few years later an X-ray installation or department would be regarded as an essential part of the equipment of every hospital. Other uses of the rays are in metallurgy and engineering as a means of discovering faults in castings or parts of machines, and the latest application of the rays to practical ends is in the determination of the structure, and corresponding strength, of hair, wool, and fibre used in the textile industries.

THERMIONIC VALVES

The development of the thermionic valve from inquiries into the electrical condition inside the bulb of an incandescent lamp provides a similar example of practical services of scientific research. So long ago as 1884 Mr. Edison discovered that an insulated metal plate sealed inside an incandescent electric lamp within the carbon filament which was then used has the same potential or electrical state as the negative electrode of the lamp. No current would pass, therefore, between the plate and the negative terminal, but a current was found to flow from the plate to the positive terminal. A few years later Sir Ambrose Fleming communicated to the Royal Society the results of a long series of researches upon this "Edison effect"; but there was no suggestion at the time that the investigations had any practical value. The one-way current is, however, a valve effect, and upon it is based the construction of every thermionic valve used in wireless communication. Sir Ambrose Fleming himself, in 1904, applied the principle to the invention of a detector of high-frequency electric oscillations, and three years later Dr. Lee de Forest introduced into the bulb the separate grid between the plate and filament which converted the detector into a relay or amplifier of the type used for reception in broadcasting and also for the generation of electric oscillations of high frequency sent out from transmitting stations. In Great Britain nearly 4,000,000 licences to possess and use broadcast receiving sets are now issued annually, bringing to the State a direct contribution of well over £500,000 and indirectly supporting a great industry created by research.

Until the thermionic valves had been discovered the range of telephonic communication through submarine or underground lines was greatly restricted. Sir Thomas Purves, Engineer-in-Chief of the Post Office, has recently pointed out that whereas eight years ago it was only possible for the British telephone user to communicate with Paris and Brussels, to-day anyone can speak from any telephone in Great Britain to about 90 per cent. of the telephone stations of the world. The harnessing of the electron has made possible the use of light-gauge cables, and where valve repeater stations are available these cables will work to practically any terrestrial distance.

Preceding the extension of telephonic communications by the introduction of valve repeaters was the electrical "loading" of cables. The speech currents along wires become attenuated and distorted as they travel from the point of origin, and Oliver Heaviside's work on the theory of these waves of transmission suggested means of avoiding distortion by distributing inductance along the circuit, either continuously by a wrapping of iron wire or tape round the conductor, or by inductance coils suitably spaced—the so-called "loading coils." Iron was first used in this manner for loading, but research by the Western Electric Company led to the production of a new material called permalloy, consisting of about four-fifths nickel and one-fifth iron, and having in some cases greatly superior properties for this purpose. Further research has led to the discovery of other important magnetic alloys for loading. The study of Heaviside's electrical theories and the adoption of continuously "loaded" submarine telegraph cables have resulted in a great increase in speed of signalling and in a great extension of the distance over which submarine cables can be used for telegraphic communication.

WORK ON METALS

It would be easy to cite many other examples of applications of scientific research to electrical development. The work of Davy and Faraday in the Royal Institution laid the foundations of electro-chemistry, represented in industry by the refining of copper and other metals, the manufacture of aluminium, and other practical processes. Moissan designed his electric furnace to carry out a series of laboratory experiments, and he prepared with it a number of metals in a high degree of purity. More than 1,000,000 tons of electric steel, equal in quality to the best crucible steel, is now made annually in electric furnaces: and other important industrial products manufactured in them are calcium carbide and carborundum.

With such convincing evidence of the financial advantage and public benefit derived from scientific research, particularly in the province of electrical engineering, it would seem to be unnecessary to urge that electrical manufacturers and supply companies might reasonably be expected to devote a fraction of one per cent. of their profits to research, whether in university laboratories or by cooperative effort. Leaving purely scientific investigations out of consideration, there are many technical problems awaiting solution, and great savings and economies may be confidently anticipated from systematic research into them, yet the funds provided to the British Electrical and Allied Industries Research Association for such work are a very meagre return for benefits received or likely to be realized. If the Faraday centenary celebration this year should lead to a wider understanding and more generous recognition of both scientific and industrial research from manufacturers and corporations who profit by the results, it will have achieved a most useful national purpose.